CERTIFICATE

I, Tomomi Nishikawa residing at Auhofstrasse 130/12, A-1130 Wien, Austria, hereby certify that I am the translator of the attached document, namely a Certified Copy of Japanese Patent Application No. 2002-251675 and certify that the following is a true translation to the best of my knowledge and belief.

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Signature of Translator

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[Name of Document] SPECIFICATION

[Title of the Invention] THIN-FILM TRANSISTOR, SWITCHING CIRCUIT, ACTIVE ELEMENT SUBSTRATE, ELECTRO-OPTICAL DEVICE, ELECTRONIC APPARATUS, THERMAL HEAD, DROPLET EJECTING HEAD, PRINTER, AND THIN-FILM-TRANSISTOR DRIVING AND LIGHT-EMITTING DISPLAY DEVICE

[Claims]

[Claim 1]

A thin-film transistor comprising an active region, and a source region and a drain region provided at both sides of the active region,

wherein the source region and the drain region include regions adjacent to the active region, the adjacent regions including lightly doped impurity regions with an impurity concentration less than that of the drain region, and

wherein the lightly doped impurity regions are provided in an asymmetrical form in which the lightly doped impurity region in the source region is smaller than that in the drain region.

[Claim 2]

A thin-film transistor according to claim 1, wherein the length, in the longitudinal direction of a channel, of the lightly doped impurity region in the drain region is longer than that of the lightly doped impurity region in the source region.

[Claim 3]

A thin-film transistor according to claim 1, wherein the lightly doped impurity region is provided only in the drain region.

[Claim 4]

A thin-film transistor according to any one of claims 1 to 3, further comprising a gate electrode provided at a position facing the active region, with an insulating layer

provided therebetween,

wherein the boundary between each lightly doped impurity region and the active region approximately matches one end of the gate electrode.

[Claim 5]

A switching circuit comprising a first transistor that is provided in a load current path and that controls the load current and a second transistor that activates the first transistor in accordance with an input signal,

wherein the first and second transistors each have an LDD structure between a source and a drain, and

wherein lightly doped impurity regions that are responsible for the LDD structure of the first transistor are provided so that one in a source region is smaller than the other in a drain region, thus adjusting the source/drain resistance to increase the load current.

[Claim 6]

A switching circuit according to claim 5, wherein the lightly doped impurity regions that are responsible for the LDD structure provided between the source and drain of the first transistor are provided asymmetrically between the source region and the drain region.

[Claim 7]

A switching circuit according to claim 5, wherein the lightly doped impurity region that is responsible for the LDD structure provided between the source and drain of the first transistor is provided only in the drain region.

[Claim 8]

An active element substrate comprising a plurality of scanning lines and a plurality of signal lines being provided on an insulated substrate so as to intersect with each other and a switching circuit for controlling a current to be supplied to a current load, the

switching circuit being provided at each intersection of the scanning lines and the signal lines,

wherein a switching circuit as set forth in any one of claims 5 to 7 is used as the switching circuit.

[Claim 9]

An electro-optical device comprising:

first and second electrodes that face each other;

an electro-optical element provided between the first electrode and the second electrode; and

a switching circuit that is connected to the first electrode and that controls a current to be supplied to the electro-optical element,

wherein a switching circuit as set forth in any one of claims 5 to 7 is used as the switching circuit.

[Claim 10]

An electro-optical device according to claim 9, wherein the electro-optical element includes at least one of an electroluminescent element, an electrophotoluminescent element, a plasma light-emitting element, an electrophoresis element, and a liquid crystal element.

[Claim 11]

An electronic apparatus comprising an electro-optical device as set forth in claim 9 or 10 serving as a display unit.

[Claim 12]

A thermal head incorporated in a thermal transfer printer, comprising:

a plurality of heating elements and a plurality of switching circuits for controlling the current to be supplied to the corresponding heating elements,

wherein a switching circuit as set forth in any one of claims 5 to 7 is used as each of the switching circuits.

[Claim 13]

A droplet ejecting head for generating a bubble in a solution to be ejected by heat generated by a heating element and ejecting the solution to be ejected from an ejection hole,

wherein a switching circuit as set forth in any one of claims 5 to 7 is used as a switching circuit for controlling the current to be supplied to the heating element.

[Claim 14]

A printer comprising a thermal head as set forth in claim 12 or a droplet ejecting head as set forth in claim 13.

[Claim 15]

A thin-film-transistor driving and light-emitting display device comprising a plurality of scanning lines and a plurality of signal lines being provided in a matrix, and a switching thin-film transistor, a driving thin-film transistor, and a light-emitting element being provided at each intersection of the scanning lines and the signal lines,

wherein the switching thin-film transistor samples the potential of the signal line when the corresponding scanning line has an ON potential,

the driving thin-film transistor controls the light-emitting state of the light-emitting element in accordance with the sampled potential, and

in the driving thin-film transistor, a lightly doped region is provided only in a drain region.

[Claim 16]

A thin-film-transistor driving and light-emitting display device comprising a plurality of scanning lines and a plurality of signal lines being provided in a matrix, and a

switching thin-film transistor, a driving thin-film transistor, and a light-emitting element being provided at each intersection of the scanning lines and the signal lines,

wherein the switching thin-film transistor samples the potential of the signal line when the corresponding scanning line has an ON potential,

the driving thin-film transistor controls the light-emitting state of the light-emitting element in accordance with the sampled potential, and

in the driving thin-film transistor, lightly doped regions are provided in both a source region and a drain region, and

the length of the lightly doped region in the drain region is longer than the length of the lightly doped region in the source region.

[Detailed Description of the Invention]

[Technical Field of the Invention]

The present invention relates to thin-film transistors, and more specifically, it relates to a thin-film transistor for use in applications requiring relatively large amounts of current (for example, applications for driving light-emitting elements such as organic EL elements and the like).

[Description of the Related Art]

Recently, research, development, and commercialization of thin-film-transistor driving and light-emitting-diode display devices, which are one type of thin-film-transistor driving and light-emitting display devices, have been actively conducted (T. Shimoda, M. Kimura, et al., Proc. Asia Display '98, 217; M. Kimura, et al., IEEE Trans. Electron. Devices 46 (1999), 2282; T. Shimoda, M. Kimura, et al., Dig. SID '99, 372; M. Kimura et al., Proc. Euro Display '99 Late-News Papers, 71; M. Kimura, et al., Proc. Euro Display '99 171; S.W.-B. Tam, M. Kimura, et al., Proc. IDW '99, 175; M. Kimura, et al., J. SID 8, 93 (2000); M. Kimura, et al., Dig. AM-LCD 2000, 245; and S.W.-B Tam, M. Kimura, et al., Proc. IDW 2000, 243).

Fig. 1 is an equivalent circuit diagram of a pixel in a known thin-film-transistor driving and light-emitting display device. A plurality of scanning lines 11 and a plurality of signal lines 12 are arranged in a matrix. At each of the intersections of the scanning lines 11 and the signal lines 12, a switching thin-film transistor 13, a driving thin-film transistor 14, and a light-emitting element 15 are provided. The switching thin-film transistor 13 samples the potential of the signal line 12 when the corresponding scanning line 11 has an ON potential. The driving thin-film transistor 14 controls the light-emitting state of the corresponding light-emitting element 15 on the basis of the potential sampled by the corresponding switching thin-film transistor 13.

Fig. 2 is a structural drawing of a driving thin-film transistor and a light-emitting element in the known thin-film-transistor driving and light-emitting display device. In a driving thin-film transistor 21, an active region 23 and heavily doped regions 26 are directly connected to each other in both a source region 24 and a drain region 25 (self-aligned structure). With the self-aligned structure, the driving thin-film transistor 21 allows a large current to flow through a light-emitting element 31, thus achieving a high-intensity thin-film-transistor driving and light-emitting display device.

[Problems to be Solved by the Invention]

Since the driving thin-film transistor 21 has the self-aligned structure, a large current is allowed to flow through the light-emitting element 31. The self-aligned structure is known to have a tendency to deteriorate over time (S. Inoue, et al., Dig. SID '99, 452 and Y. Uraoka, et al., Dig. AM-LCD '01, 179). Since the driving thin-film transistor 21 allows a direct current to flow at all times, the driving thin-film transistor 21 tends to deteriorate over time.

It is an object of the present invention to prevent the performance of a thin-film transistor for use in a thin-film-transistor driving and light-emitting display device from deteriorating over time while maintaining a function of allowing a relatively large current to flow.

[Means for Solving the Problems]

In order to achieve the foregoing objects, a thin-film transistor of the present invention includes an active region, and a source region and a drain region provided at both sides of the active region. The source region and the drain region include regions adjacent to the active region, the adjacent regions including lightly doped impurity regions with an impurity concentration less than that of the drain region. The lightly doped impurity regions are provided in an asymmetrical form in which the lightly doped

impurity region in the source region is smaller than that in the drain region.

By reducing the size of the lightly doped impurity region (LDD region) in the source region, the source/drain electric resistance is reduced, thus allowing a larger current to flow. The LDD region in the drain region has a certain area. Accordingly, generation of hot carriers (hot electrons) between the active region and the drain region is suppressed, preventing the performance of the thin-film transistor from deteriorating over time. In other words, according to the present invention, a thin-film transistor that satisfies two needs, that is, maintaining a function of allowing a relatively large current to flow and preventing the performance from deteriorating over time, is realized.

Preferably, the length, in the longitudinal direction of a channel, of the lightly doped impurity region in the drain region is longer than that of the lightly doped impurity region in the source region.

Preferably, the lightly doped impurity region is provided only in the drain region.

Preferably, the thin-film transistor further includes a gate electrode provided at a position facing the active region, with an insulating layer provided therebetween. The boundary between each lightly doped impurity region and the active region may approximately match one end of the gate electrode. The position at which the gate electrode is provided is determined on the basis of any of the following structures, including a bottom gate structure in which the gate electrode is provided below the active region (the substrate side) and a top gate structure in which the gate electrode is provided above the active region. In particular, the top gate structure makes it possible to have a so-called self-aligned gate structure in which a source region and a drain region are provided by ion implantation with the gate electrode serving as a mask.

A switching circuit of the present invention includes a first transistor that is provided in a load current path and that controls the load current and a second transistor

that activates the first transistor in accordance with an input signal. The first and second transistors each have an LDD structure between a source and a drain. Lightly doped impurity regions that are responsible for the LDD structure of the first transistor are provided so that one in a source region is smaller than the other in a drain region, thus adjusting the source/drain resistance to increase the load current.

With the foregoing arrangement, the electric resistance between the source and the drain of the first transistor is reduced to increase the load current. Also, generation of hot carriers between the active region and the drain region is suppressed, preventing the performance of the thin-film transistor from deteriorating over time. Since the second transistor has the LDD structure, reliability is improved. A combination of the first and second thin-film transistors realizes a switching circuit that has a relatively high current driving capability and high reliability.

Preferably, the lightly doped impurity regions that are responsible for the LDD structure provided between the source and drain of the first transistor are provided asymmetrically between the source region and the drain region.

Preferably, the lightly doped impurity region that is responsible for the LDD structure provided between the source and the drain of the first transistor is provided only in the drain region.

According to the present invention, an active element substrate including the above-described switching circuit is provided. Specifically, an active element substrate of the present invention includes a plurality of scanning lines and a plurality of signal lines being provided on an insulating substrate so as to intersect with each other and a switching circuit for controlling a current to be supplied to a current load, the switching circuit being provided at each intersection of the scanning lines and the signal lines. The above-described switching circuit according to the present invention is used as the switching

circuit.

According to the present invention, an electro-optical device including the above-described switching circuit is provided. Specifically, an electro-optical device of the present invention includes first and second electrodes that face each other; an electro-optical element provided between the first electrode and the second electrode; and a switching circuit that is connected to the first electrode and that controls a current to be supplied to the electro-optical element. The above-described switching circuit according to the present invention is used as the switching circuit.

Preferably, the above-described electro-optical element includes at least one of an electroluminescent element, an electrophotoluminescent element, a plasma light-emitting element, an electrophoresis element, and a liquid crystal element.

According to the present invention, an electronic apparatus is provided including the above-described electro-optical device according to the present invention serving as a display unit. The electronic apparatus includes a video camera, a cellular phone, a personal computer, a personal digital assistant (PDA), and various other apparatuses. By using the electro-optical device according to the present invention, an electronic apparatus with a display unit having excellent display characteristics is realized.

The above-described switching circuit according to the present invention is suitably applicable to a thermal head incorporated in a thermal transfer printer. Specifically, a thermal head of the present invention is a thermal head incorporated in a thermal transfer printer and includes a plurality of heating elements and a plurality of switching circuits for controlling the current to be supplied to the corresponding heating elements. The above-described switching circuit according to the present invention is used as the switching circuit.

The above-described switching circuit according to the present invention is suitably

applicable to a droplet ejecting head (so-called inkjet head) used by being incorporated in an inkjet printer. Specifically, a droplet ejecting head of the present invention generates a bubble in a solution to be ejected by heat generated by a heating element and ejects the solution to be ejected from an ejection hole. The above-described switching circuit according to the present invention is used as a switching circuit for controlling the current to be supplied to the heating element.

According to the present invention, a printer is provided including the above-described thermal head or the droplet ejecting head according to the present invention.

The present invention as set forth in claim 15 is a thin-film-transistor driving and light-emitting display device including a plurality of scanning lines and a plurality of signal lines being provided in a matrix, and a switching thin-film transistor, a driving thin-film transistor, and a light-emitting element being provided at each intersection of the scanning lines and the signal lines. The switching thin-film transistor samples the potential of the signal line when the corresponding scanning line has an ON potential. The driving thin-film transistor controls the light-emitting state of the light-emitting element in accordance with the sampled potential. In the driving thin-film transistor, a lightly doped region is provided only in a drain region (one-sided LDD structure).

The present invention as set forth in claim 16 is a thin-film-transistor driving and light-emitting display device comprising a plurality of scanning lines and a plurality of signal lines being provided in a matrix, and a switching thin-film transistor, a driving thin-film transistor, and a light-emitting element being provided at each intersection of the scanning lines and the signal lines. The switching thin-film transistor samples the potential of the signal line when the corresponding scanning line has an ON potential. The driving thin-film transistor controls the light-emitting state of the light-emitting element in accordance with the sampled potential. Lightly doped regions are provided in

both a source region and a drain region. The length of the lightly doped region in the drain region is longer than the length of the lightly doped region in the source region (asymmetrical LDD structure).

In general, the LDD structure prevents deterioration over time (Takayuki Ohno, Yukiharu Uraoka, et al., Shingakugihou (Technical Report of IEICE) ED2000-7, 43(2000)). Since the present invention employs the one-sided LDD structure or the asymmetrical LDD structure, the driving thin-film transistor of the thin-film-transistor driving and light-emitting display device maintains the function of allowing a large current to flow while being prevented from deteriorating over time. Since the current direction of the light-emitting element is determined, the source region side and the drain region side of the driving thin-film transistor are determined. Therefore, there will be no confusion as to the providing of the one-sided LDD structure or the asymmetrical LDD structure.

Compared with a both-sided LDD structure, the present invention can allow a large current to flow even when the driving thin-film transistor applies a low voltage. The voltage applied to the scanning lines and the signal lines can be reduced, and hence the power consumption of a built-in drive circuit and an external drive circuit can be reduced. Furthermore, narrowing of the driving thin-film transistor is made possible, leading to improvement of the light-emitting region ratio (the ratio of the light-emitting region to the entire pixel area), reduction of the current density of the light-emitting element, and elongation of life of the light-emitting element.

[Description of the Embodiments]

With reference to the drawings, preferred embodiments of the present invention will be described below. In the present specification, a thin-film transistor used to allow a relatively large current to flow is referred to as a "driving thin-film transistor".

(First Embodiment)

Fig. 3 is a structural drawing of a driving thin-film transistor and a light-emitting element according to a first embodiment of the present invention. As shown in Fig. 3, in a driving thin-film transistor 21 of the first embodiment, a lightly doped region 27 is provided only in a drain region 25, resulting in a one-sided LDD (lightly Doped Drain) structure.

More specifically, as shown in Fig. 3, the driving thin-film transistor 21 is to control a current to be supplied to a light-emitting element 31 and is provided on a substrate 20. Although an organic EL (electroluminescent) element is used as the light-emitting element 31 in this embodiment, the light-emitting element 31 is not limited to this type.

The driving thin-film transistor 21 includes a gate electrode 22, an active region 23, a source region 24, and the drain region 25.

The active region 23 is provided on the substrate 20 at a position approximately facing the gate electrode 22. The active region 23 functions as a current path. An insulating layer made of SiO_2 or the like is provided between the active region 23 and the gate electrode 22.

The source region 24 includes a heavily doped region 26 that is heavily doped with impurities (dopant). The heavily doped region 26 is connected via a source electrode to a current source (not shown).

The drain region 25 includes a heavily doped region 26 that is heavily doped with impurities and the lightly doped region (lightly doped impurity region) 27 that is lightly doped with impurities. The heavily doped region 26 is connected via a drain electrode to the light-emitting element 31.

One end of the lightly doped region 27 is connected to the active region 23, and the other end of the lightly doped region 27 is connected to the heavily doped region 26. As

shown in Fig. 3, the boundary between the active region 23 and the lightly doped region 27 approximately matches one end of the gate electrode 22.

As discussed above, in the driving thin-film transistor 21 of the first embodiment, no lightly doped region (LDD region) is provided in the source region 24, and the lightly doped region (LDD region) 27 is provided only in the drain region 25, thus realizing an asymmetrical LDD structure. Accordingly, the electric resistance between source and drain is reduced to allow a larger current to flow. At the same time, generation of hot carriers between the active region 23 and the drain region 25 is suppressed, thus preventing the performance of the thin-film transistor from deteriorating over time.

(Second Embodiment)

Fig. 4 is a structural drawing of a driving thin-film transistor and a light-emitting element according to a second embodiment of the present invention. As shown in Fig. 4, in the driving thin-film transistor 21, the lightly doped regions 27 are provided in both the source region 24 and the drain region 25. The lightly doped region 27 in the drain region 25 is longer than the lightly doped region 27 in the source region 24, resulting in an asymmetrical LDD structure. In the driving thin-film transistor 21 shown in Fig. 4, the same reference numerals are given to components corresponding to those of the first embodiment, and detailed descriptions of the common portions are omitted.

In the driving thin-film transistor 21 shown in Fig. 4, the source region 24 includes the heavily doped region 26, which is heavily doped with impurities, and the lightly doped region 27, which is lightly doped with impurities. One end of the lightly doped region 27 is connected to the active region 23, and the other end of the lightly doped region 27 is connected to the heavily doped region 26. As shown in Fig. 4, the boundary between the active region 23 and the lightly doped region 27 approximately matches one end of the gate electrode 22.

The drain region 25 includes the heavily doped region 26, which is heavily doped with impurities, and the lightly doped region 27, which is lightly doped with impurities. One end of the lightly doped region 27 is connected to the active region 23, and the other end of the lightly doped region 27 is connected to the heavily doped region 26. As shown in Fig. 4, the boundary between the active region 23 and the lightly doped region 27 approximately matches the other end of the gate electrode 22.

Fig. 5 is an illustration for describing the length of the lightly doped region 27 in the drain region 25 and the length of the lightly doped region 27 in the source region 24. In the illustration, a range covering the lightly doped regions 27 is enlarged.

As shown in Fig. 5, in this embodiment, the lightly doped regions 27 are provided so that length L1, in the longitudinal direction of the channel (A direction in the illustration), of the lightly doped region 27 in the drain region 25 is greater than length L2, in the longitudinal direction of the channel, of the lightly doped region 27 in the source region 24. The lightly doped regions 27 are provided so that the cross sectional areas of faces orthogonal to the current direction (faces orthogonal to the page) are approximately equal.

As discussed above, in the driving thin-film transistor 21 of the second embodiment, the lightly doped regions 27 differ from each other in length, in the longitudinal direction of the channel, resulting in an asymmetrical LDD structure. Accordingly, the electric resistance between source and drain is reduced to allow a larger current to flow. At the same time, generation of hot carriers between the active region 23 and the drain region 25 is suppressed, thus preventing the performance of the thin-film transistor from deteriorating over time.

(Third Embodiment)

Using the driving thin-film transistor 21 according to the present invention, which

is described in the first or second embodiment, a switching circuit that allows a relatively large current to flow and that deteriorates slowly over time is provided. Such a switching circuit is suitable to drive a light-emitting element such as an organic EL element. A specific example of a pixel circuit using the switching circuit according to the present invention will now be described.

Since the circuit structure of a pixel circuit of a third embodiment is basically similar to the equivalent circuit of the pixel, which is shown in Fig. 1, the pixel circuit of the third embodiment is not shown. In the equivalent circuit of the pixel, which is shown in Fig. 1, the driving thin-film transistor 21 according to the present invention, which is described in the first or second embodiment, is used in place of the driving thin-film transistor 14. Accordingly, a pixel circuit that has a relatively high current driving capability and high reliability can be realized.

When a pixel circuit having a structure similar to that shown in Fig. 1 is provided using the driving thin-film transistor 21 of the first or second embodiment, a switching thin-film transistor 13 for switching on/off the driving thin-film transistor 21 may have an LDD structure. In this case, the LDD structure of the switching thin-film transistor 13 may be asymmetrical, as in the case with the driving thin-film transistor 21, or may be symmetrical. In this case, the LDD structures of both the switching thin-film transistor 13 and the driving thin-film transistor 21 are constructed by the same manufacturing process. Therefore, the manufacturing process is not extended.

An element (current load) whose load current is to be controlled by the switching circuit of this embodiment is not limited to the above-described organic EL element, but is also applicable to various electro-optical elements such as an electrophotoluminescent element, a plasma light-emitting element, an electrophoresis element, and a liquid crystal element.

An active element substrate that includes the above-described driving thin-film transistor and a display device (electro-optical device) that includes such an active element substrate will now be described.

Fig. 6 is an equivalent circuit diagram of a display device. As shown in Fig. 6, a display device 100 includes a plurality of pixel portions 111 arranged in a matrix in a display region 110, a plurality of scanning lines 112, a plurality of signal lines 113, a plurality of power lines 114, and drivers 115 and 116.

Each of the pixel portions 111 includes the above-described pixel circuit. Specifically, each pixel portion 111 includes the switching thin-film transistor 13, the light-emitting element 15, a storage capacitor 16, and the driving thin-film transistor 21.

The driver 115 supplies a control signal to the gate of the switching thin-film transistor 13 included in each pixel portion 111 via the corresponding scanning line 112. The drive 116 supplies a control signal to the source of the switching thin-film transistor 13 included in each pixel portion 111 via the corresponding signal line 113 and supplies a current to the source of the driving thin-film transistor 21 included in each pixel portion 111 via the corresponding power line 114.

In other words, the display device 100 shown in Fig. 6 includes an array substrate (active element substrate) on which the light-emitting elements 15 serving as the current loads and the like are provided. The array substrate includes the plurality of scanning lines 112 and the plurality of signal lines 113 intersecting with each other and, at each of the intersections of the scanning lines 112 and the signal lines 113, a switching circuit including the switching thin-film transistor 13 and the driving thin-film transistor 21. In other words, the active element substrate prior to its being mounted with the light-emitting element and the like may be an independent product, to which the present invention can be applied.

Various electronic apparatuses including the above-described display device 100 will now be described. Fig. 7 includes illustrations of specific examples of electronic apparatuses to which the display device 100 is applicable.

Fig. 7(a) shows an application to a cellular phone. A cellular phone 230 includes an antenna 231, an audio output unit 232, an audio input unit 233, an operation unit 234, and the display device 100 of the present invention. As discussed above, the display device according to the present invention can be used as a display unit.

Fig. 7(b) shows an application to a video camera. A video camera 240 includes an image receiving unit 241, an operation unit 242, an audio input unit 243, and the display device 100 of the present invention. As discussed above, the display device according to the present invention can be used as a finder or a display unit.

Fig. 7(c) shows an application to a mobile personal computer. A computer 250 includes a camera 251, an operation unit 252, and the display device 100 of the present invention. As discussed above, the display device according to the present invention can be used as a display unit.

Fig. 7(d) shows an application to a head mounted display. A head mounted display 260 includes a band 261, an optical system storage section 261, and the display device 100 of the present invention. As discussed above, the display device according to the present invention can be used as an image display source.

The display device 100 according to the present invention is applicable not only to the above-described examples, but also to various electronic apparatuses including a facsimile machine with a display function, a finder of a digital camera, a portable TV, and an electronic notebook.

(Fourth Embodiment)

Another example of a switching circuit including the driving thin-film transistor 21

described in the first or second embodiment is a circuit for controlling the current that flows through a heating element (hereinafter referred to as a "heating-element control circuit"). Such a heating-element control circuit is used in a print head (thermal head) in a thermal transfer printer (thermal printer) or the like. A specific description of the heating-element control circuit will now be given.

Fig. 8 is a diagram of a heating-element control circuit. In the heating-element control circuit shown in Fig. 8, the light-emitting element 15 in the pixel circuit described in the third embodiment is replaced by a heating element 35.

Specifically, a switching circuit including the switching thin-film transistor 13 and the driving thin-film transistor 21 is provided at the intersection of the scanning line 11 and the signal line 12. The switching circuit controls the current that flows through the heating element 35.

When the heating-element control circuit shown in Fig. 8 includes the driving thin-film transistor 21 according to the first or second embodiment, the switching thin-film transistor 13 may have an LDD structure. In this case, the LDD structure of the switching thin-film transistor 13 may be asymmetrical, as in the driving thin-film transistor 21, or may be symmetrical.

A heating-element array including the heating-element control circuit described above will now be described. Fig. 9 is a diagram of the circuit configuration of a heating-element array. The heating-element array shown in the diagram includes a plurality of heating elements 35 and a control circuit 36 for controlling the current that flows through each of the heating elements 35. The control circuit 36 includes a plurality of heating-element control circuits (see Fig. 8), the number of which corresponds to the number of heating elements 35.

The heating-element array shown in Fig. 9, prior to its being mounted with the

heating elements 35, may be provided as an independent product serving as an array substrate that includes a plurality of switching circuits including a plurality of switching thin-film transistors 13 and a plurality of driving thin-film transistors 21.

A specific example of a thermal head for use in a thermal printer, which includes the above-described heating-element control circuit, will now be described. Fig. 10 includes illustrations of a specific example of a thermal head. Fig. 10(a) is a perspective view for schematically describing a thermal head according to the present invention. Fig. 10(b) is a plan view for describing a heating-element array included in the thermal head.

A thermal head 120 shown in Fig. 10 is used by being incorporated in a thermal printer. The thermal head 120 includes a heating-element array 122 that includes a plurality of heating elements 121. A thermal print medium (such as thermal paper) 126 is held between the thermal head 120 and a feed roller 124. The thermal head 120 applies heat to an arbitrary position on the print medium 126, and printing is performed. The heating-element array 122 includes the structure shown in Fig. 9. As shown in Fig. 10(b), the heating-element array 122 includes the plurality of heating elements 121 arranged in a line and a control circuit (not shown) for driving each of the heating elements 121. A thermal printer (not shown) can be provided using the thermal head 120.

The above-described thermal head 120 is also applicable to a case in which a thermal recording material (so-called ink ribbon) is provided between the thermal head 120 and the print medium 126, and printing is performed by transferring the thermal recording material to a non-thermal print medium.

Using the above-described heating-element control circuit, an inkjet head (droplet ejecting head) may be provided that employs a so-called thermal inkjet method for ejecting ink by generating bubbles in a solution to be ejected (hereinafter referred to as "ink") by heat generated by heating elements. Hereinafter the inkjet head will be

described in detail.

Fig. 11 includes illustrations of a specific example of an inkjet head. Fig. 11(a) is a perspective view for schematically describing an inkjet head according to the present invention. Fig. 11(b) is a sectional view of a portion corresponding to one of ejection holes 131, illustrating a heating element included in the inkjet head.

An inkjet head 130 shown in Fig. 11 is used by being incorporated in a thermal inkjet printer. The inkjet head 130 includes the plurality of ejection holes 131 and heating elements 133 corresponding to the respective ejection holes 131.

As shown in Fig. 11(b), the ejection hole 131 and an ink path 132 are linked together so that they communicate with one another. The heating element 133 is provided near the ejection hole 131 in the ink path 132. When a current is supplied to the heating element 133, heat generated by the heating element 133 generates a bubble 134 in ink 135 in the ink path 132, which in turn causes droplets 136 to be ejected from the ejection hole 131.

As described above, the plurality of heating elements 133 is provided, the number of which corresponds to the number of ejection holes 131. The current supplied to each of the heating elements 133 is controlled independently. The heating-element control circuit shown in Fig. 8 is applicable to a heating-element control circuit that includes the plurality of heating elements 133 and a control circuit (not shown) for driving each of the heating elements 133. A thermal inkjet printer (not shown) can be provided using the inkjet head 130.

The above-described inkjet head 130 is applicable not only to a printer, but also applicable to, for example, a droplet ejecting apparatus that supplies a desired solution (such as a plating solution or a photo-resist solution) to a desired position in a semiconductor-device manufacturing process or the like.

The present invention is not limited to the contents of the above-described embodiments. Various modifications can be made within the scope of the present invention. For example, in the first and second embodiments, the conductive type of the driving thin-film transistor 21 is p-type, and a current flows through the light-emitting element 31 in the direction from the driving thin-film transistor 21 to the light-emitting element 31. Therefore, the drain region 25 is provided at a location connected to the light-emitting element 31. In contrast, if the conductive type of the driving thin-film transistor 21 is n-type or if a current flows through the light-emitting element 31 in the direction from the light-emitting element 31 to the driving thin-film transistor 21, the drain region 25 is provided at a location that is not connected to the light-emitting element 31. Accordingly, the one-sided LDD structure or the asymmetrical LDD structure must be provided.

[Advantages]

As described above, according to the present invention, a thin-film transistor that satisfies two needs, that is, maintaining a function of allowing a relatively large current to flow and preventing deterioration over time, is realized.

According to the present invention, a switching circuit that has a relatively high current driving capability and high reliability is realized.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is an equivalent circuit diagram of a pixel in a known thin-film-transistor driving and light-emitting display device.

[Fig. 2]

Fig. 2 is a structural drawing of a driving thin-film transistor and a light-emitting element in the known thin-film-transistor driving and light-emitting display device.

[Fig. 3]

Fig. 3 is a structural drawing of a driving thin-film transistor and a light-emitting element according to a first aspect of the present invention.

[Fig. 4]

Fig. 4 is a structural drawing of a driving thin-film transistor and a light-emitting element according to a second aspect of the present invention.

[Fig. 5]

Fig. 5 is an illustration for describing the length of a lightly doped region in a drain region and the length of a lightly doped region in a source region.

[Fig. 6]

Fig. 6 is an equivalent circuit diagram of a display device.

[Fig. 7]

Fig. 7 includes illustrations of specific examples of electronic apparatuses to which the display device is applicable.

[Fig. 8]

Fig. 8 is a diagram of a heating-element control circuit.

[Fig. 9]

Fig. 9 is a diagram of the circuit configuration of a heating-element array.

[Fig. 10]

Fig. 10 includes illustrations of a specific example of a thermal head.

[Fig. 11]

Fig. 11 includes illustrations of a specific example of an inkjet head.

[Reference Numerals]

11: scanning lines

12: signal lines

13: switching thin-film transistors

14: driving thin-film transistors

15: light-emitting elements

21: driving thin-film transistors

22: light-emitting elements

23: active regions

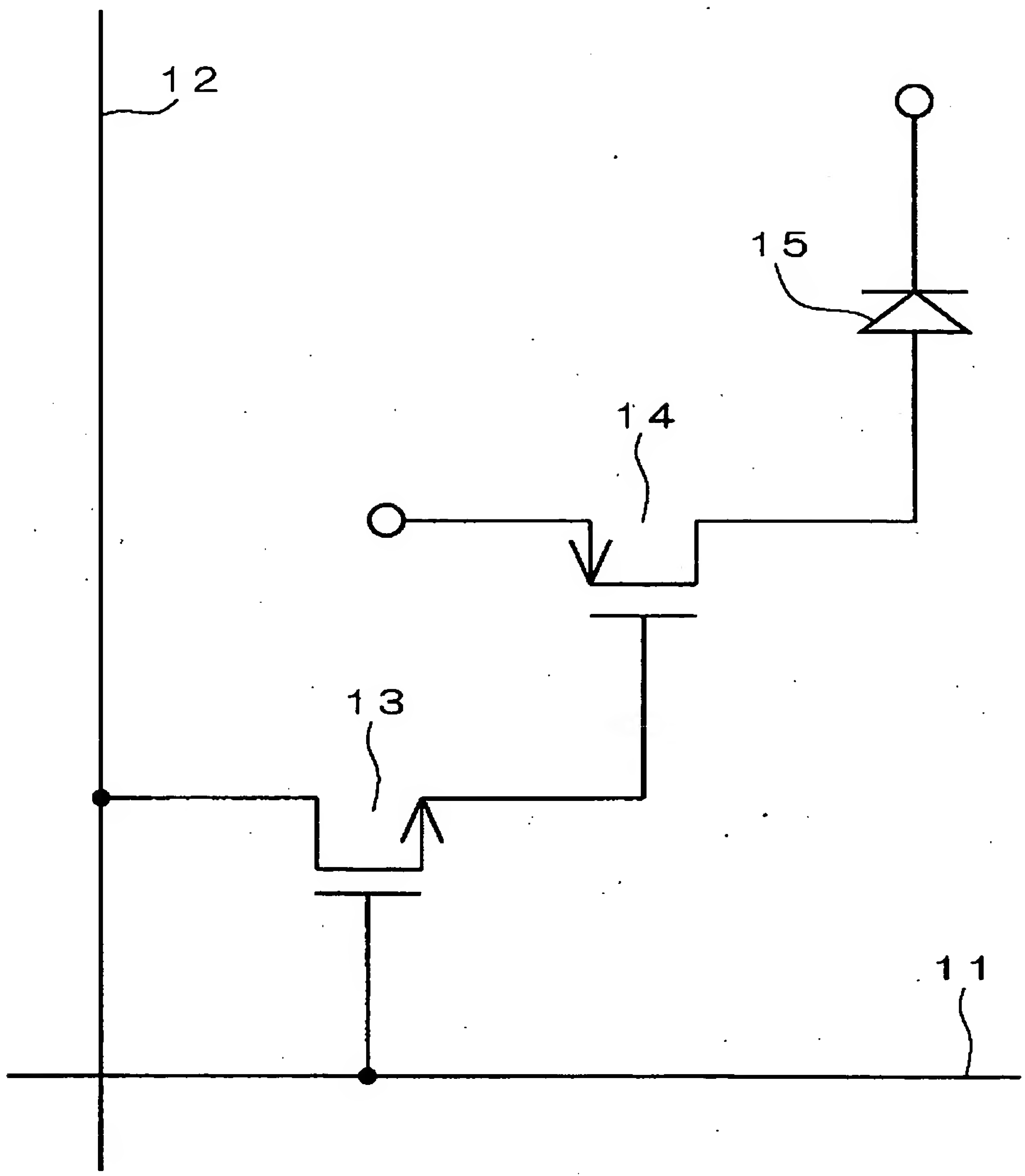
24: source regions

25: drain regions

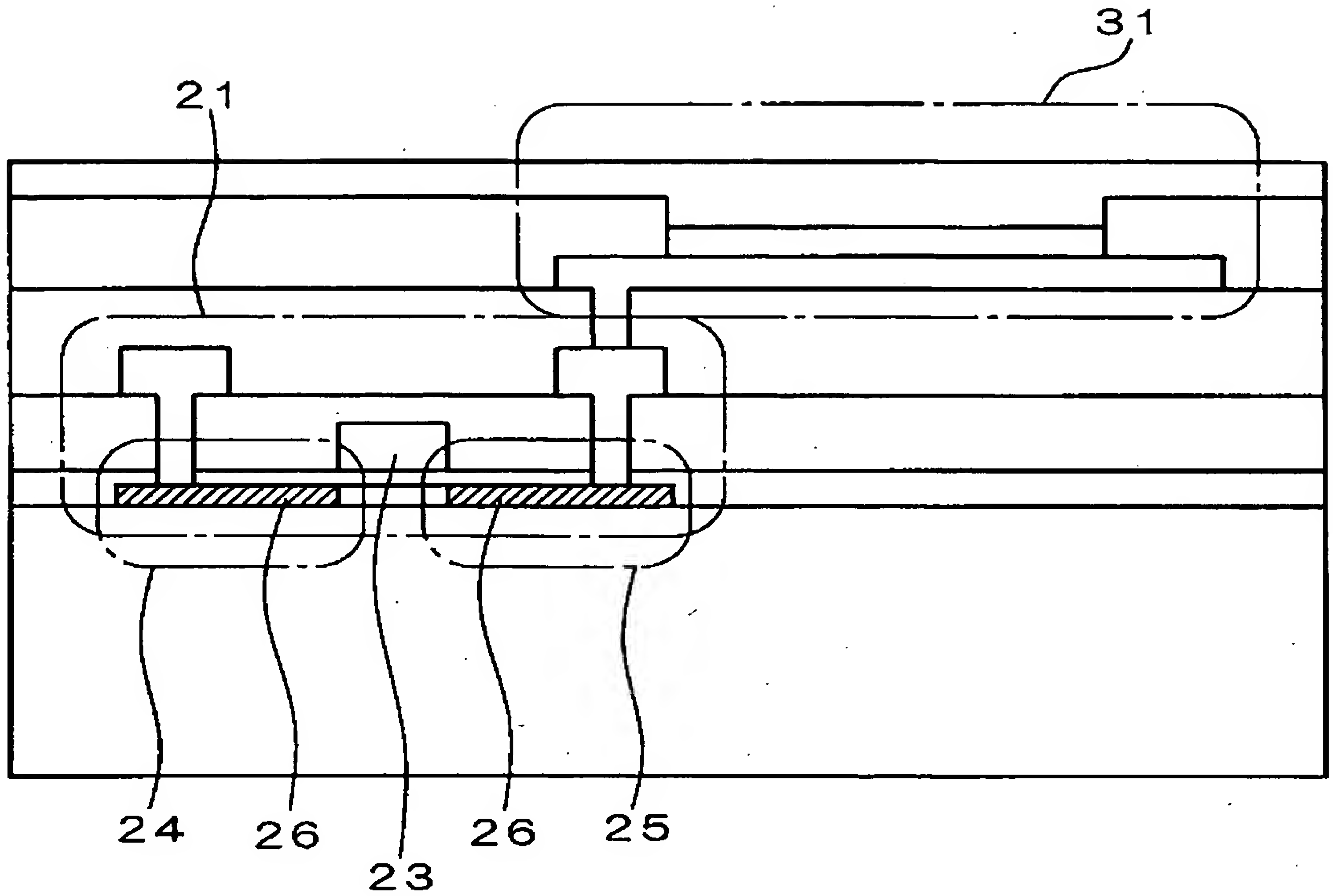
26: heavily doped regions

27: lightly doped regions

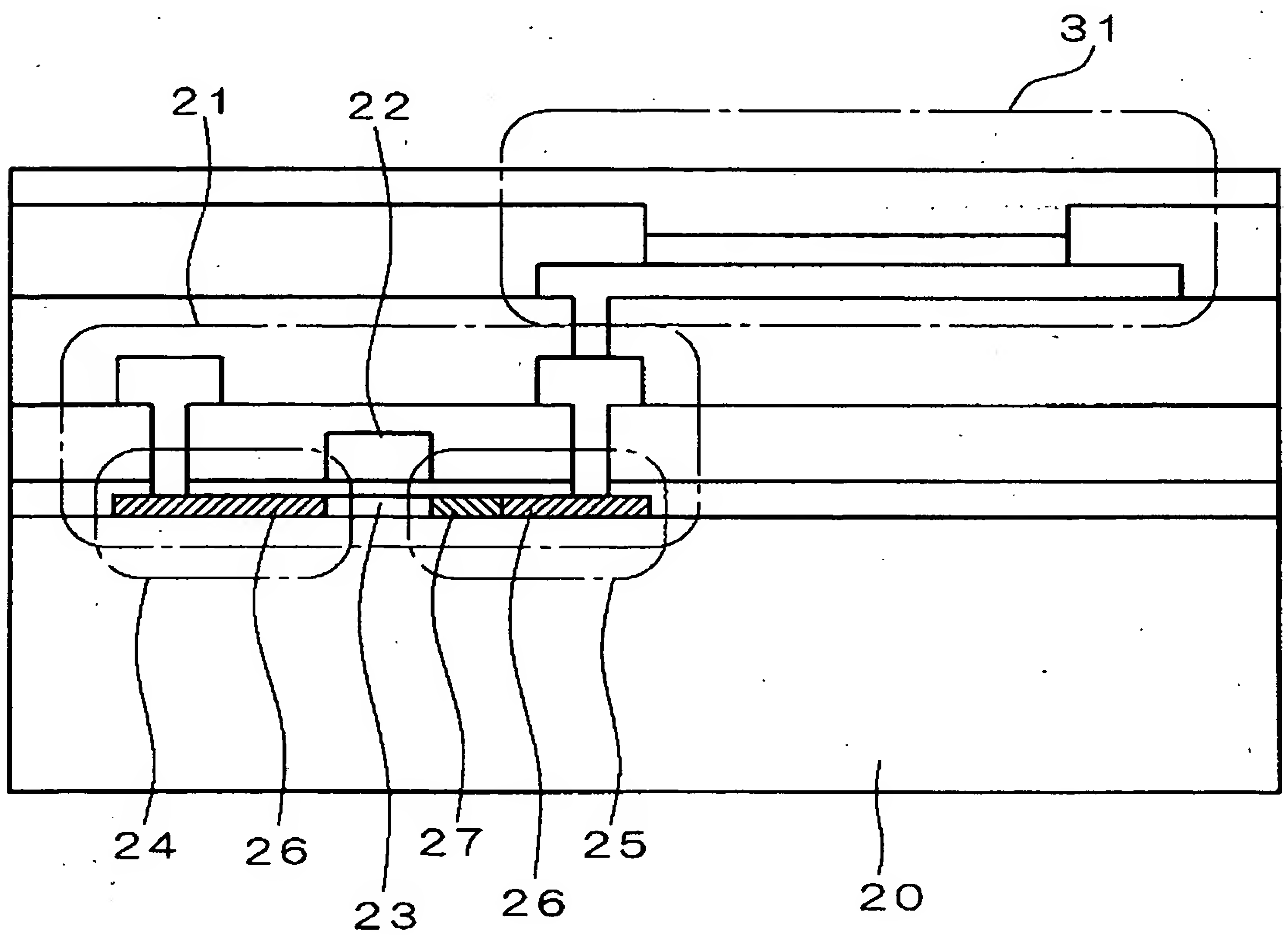
[FIG. 1]



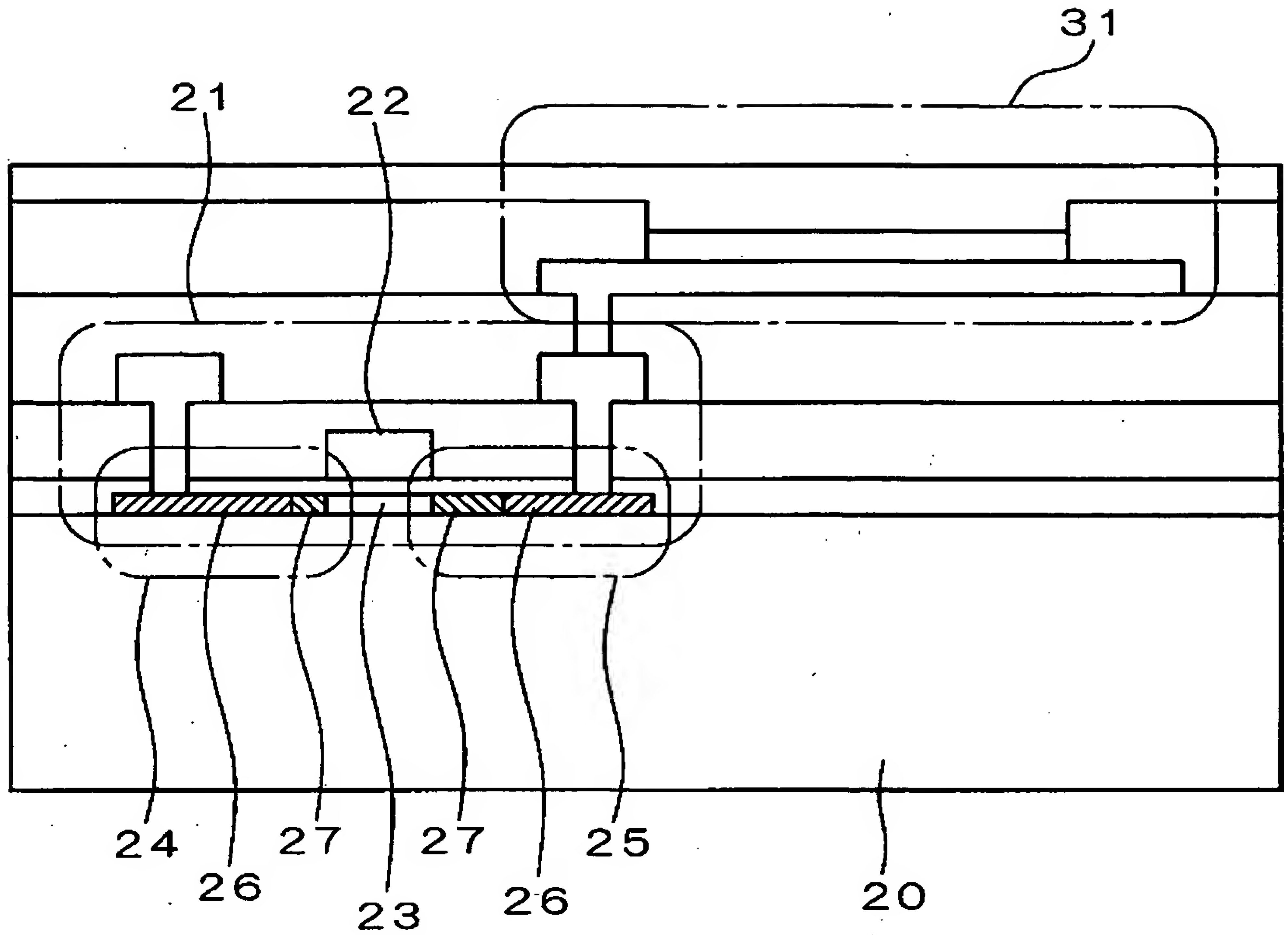
[FIG. 2]



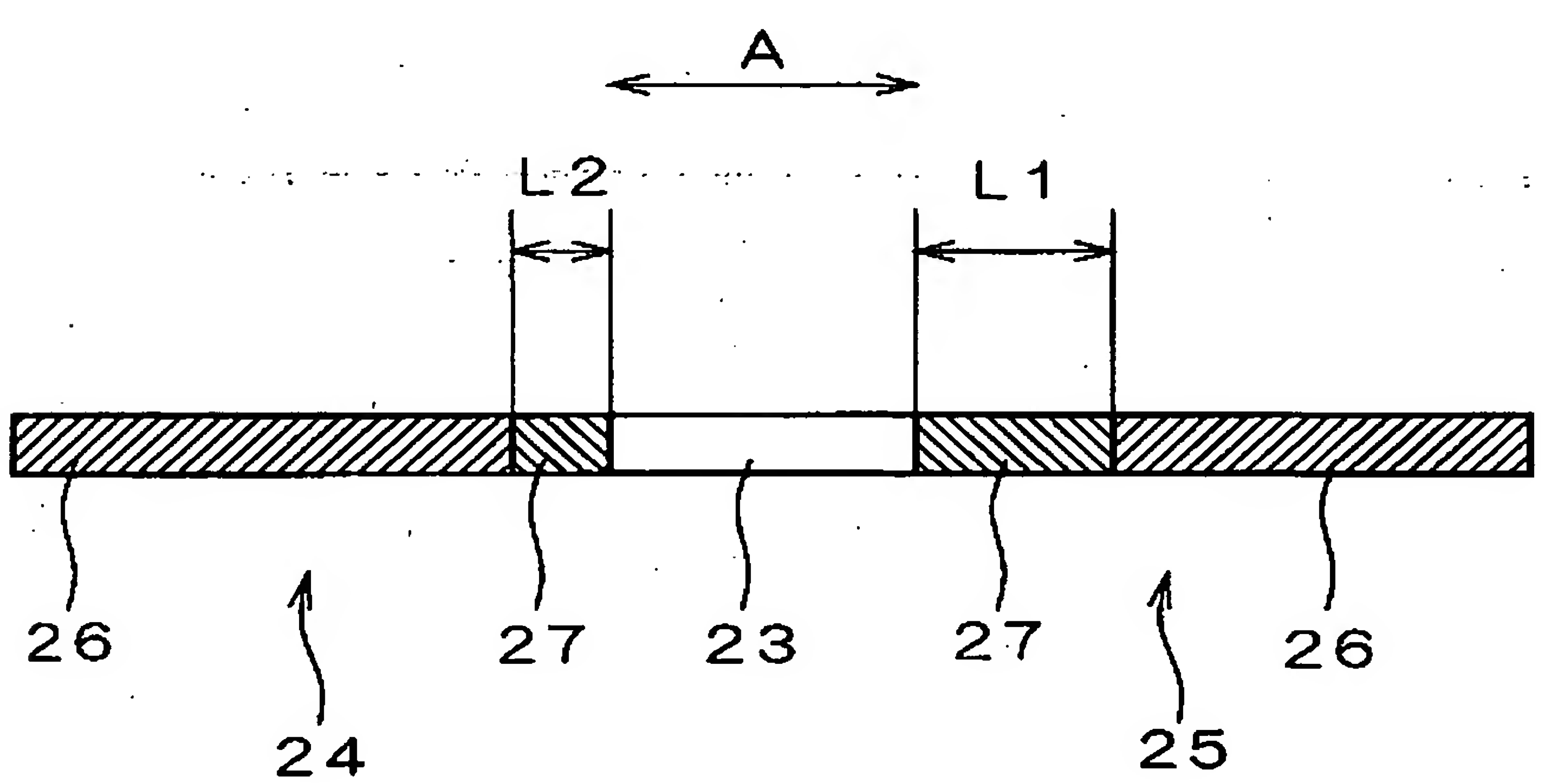
[FIG. 3]



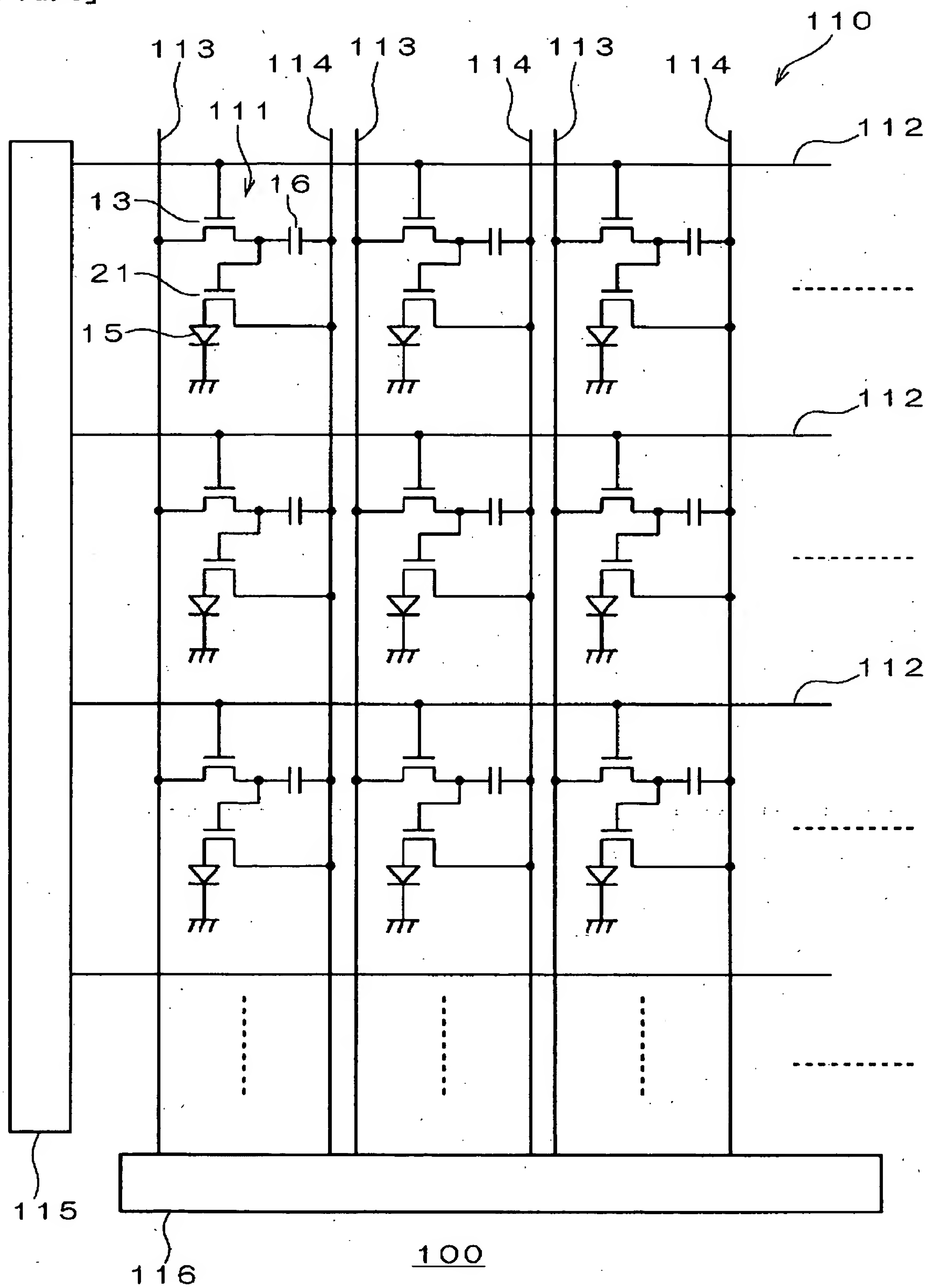
[FIG. 4]



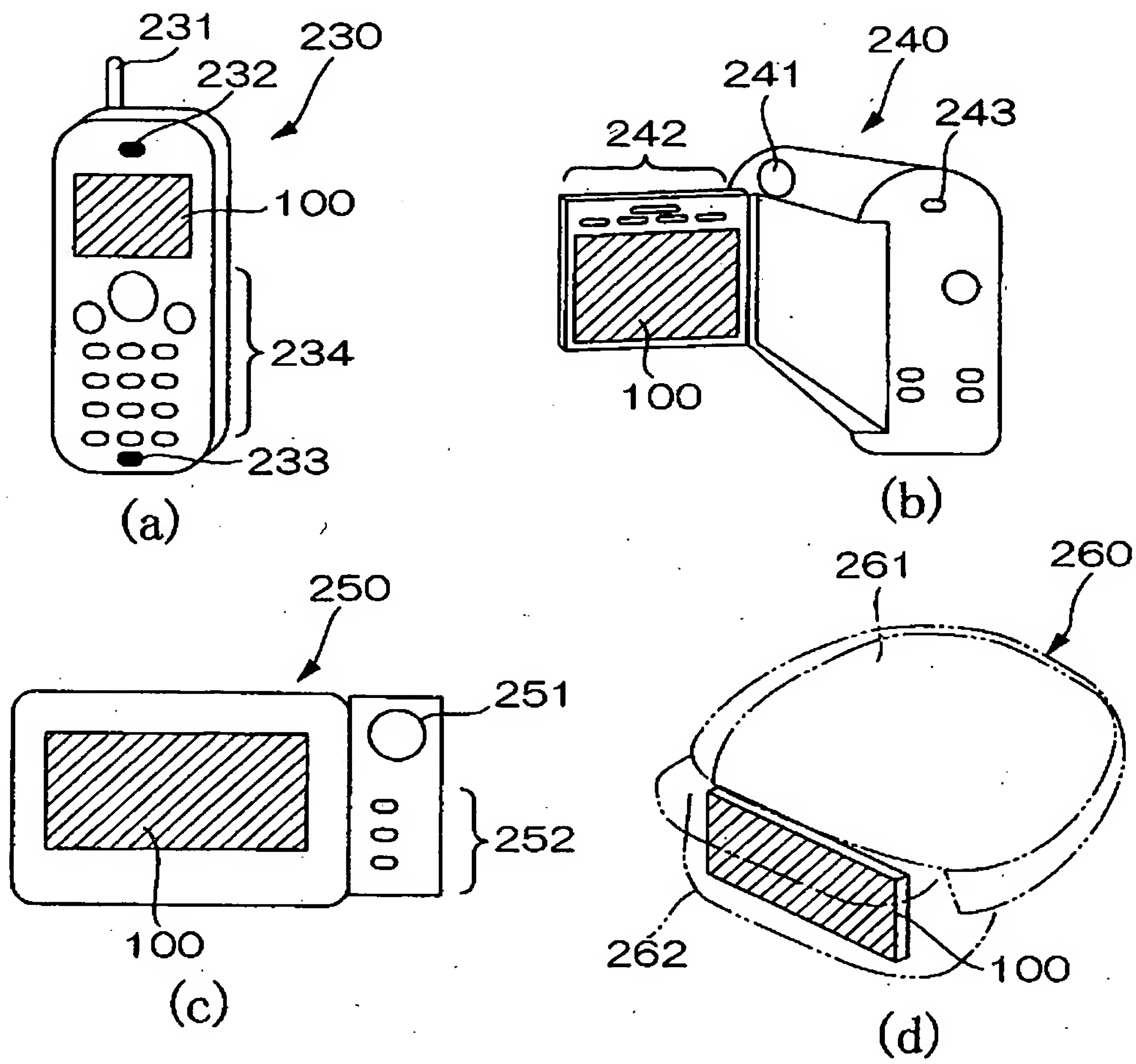
[FIG. 5]



[FIG. 6]

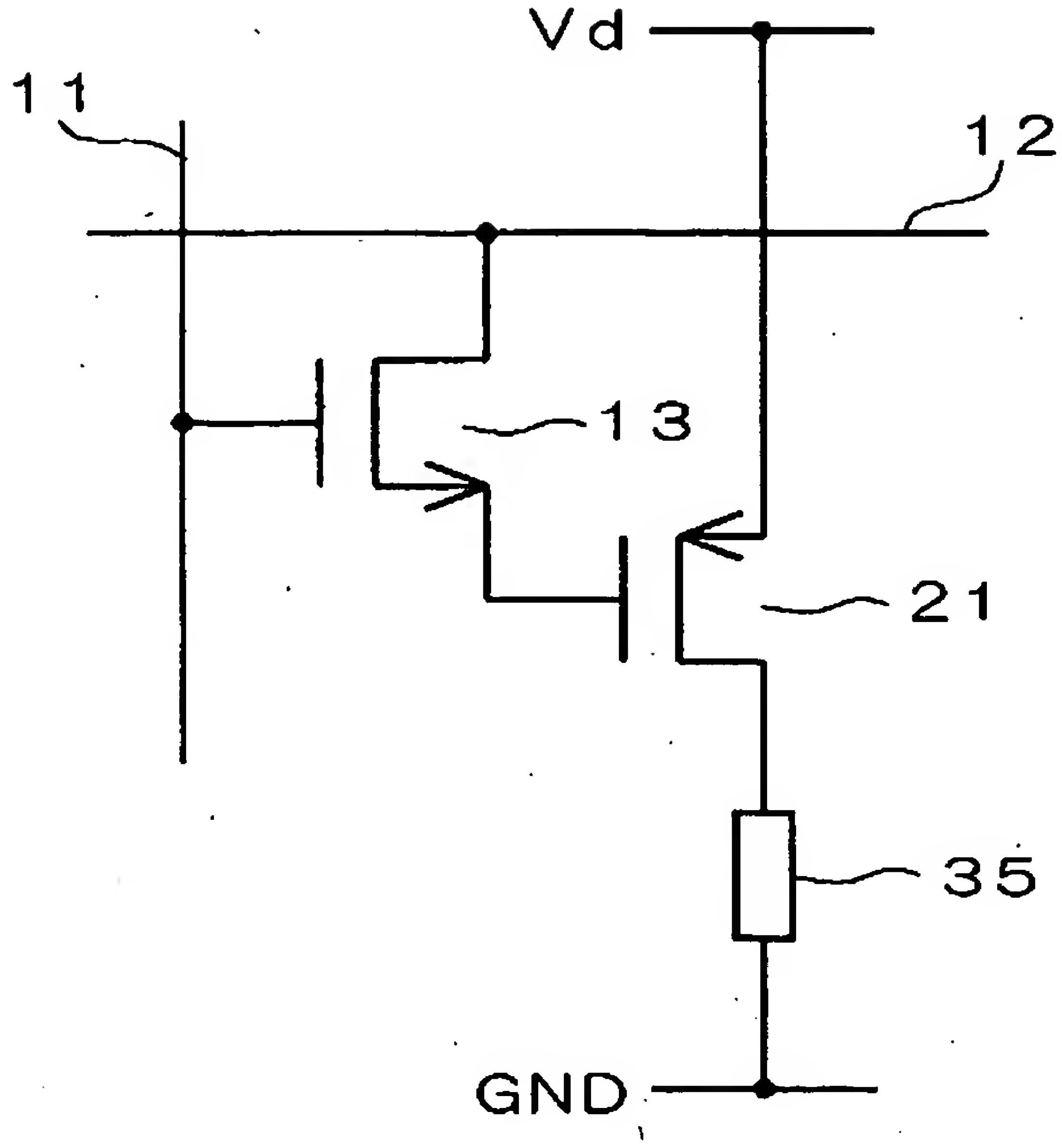

110
113
114
113
114
113
114
111
112
16
13
21
15
112
112
115
116
100

[FIG. 7]

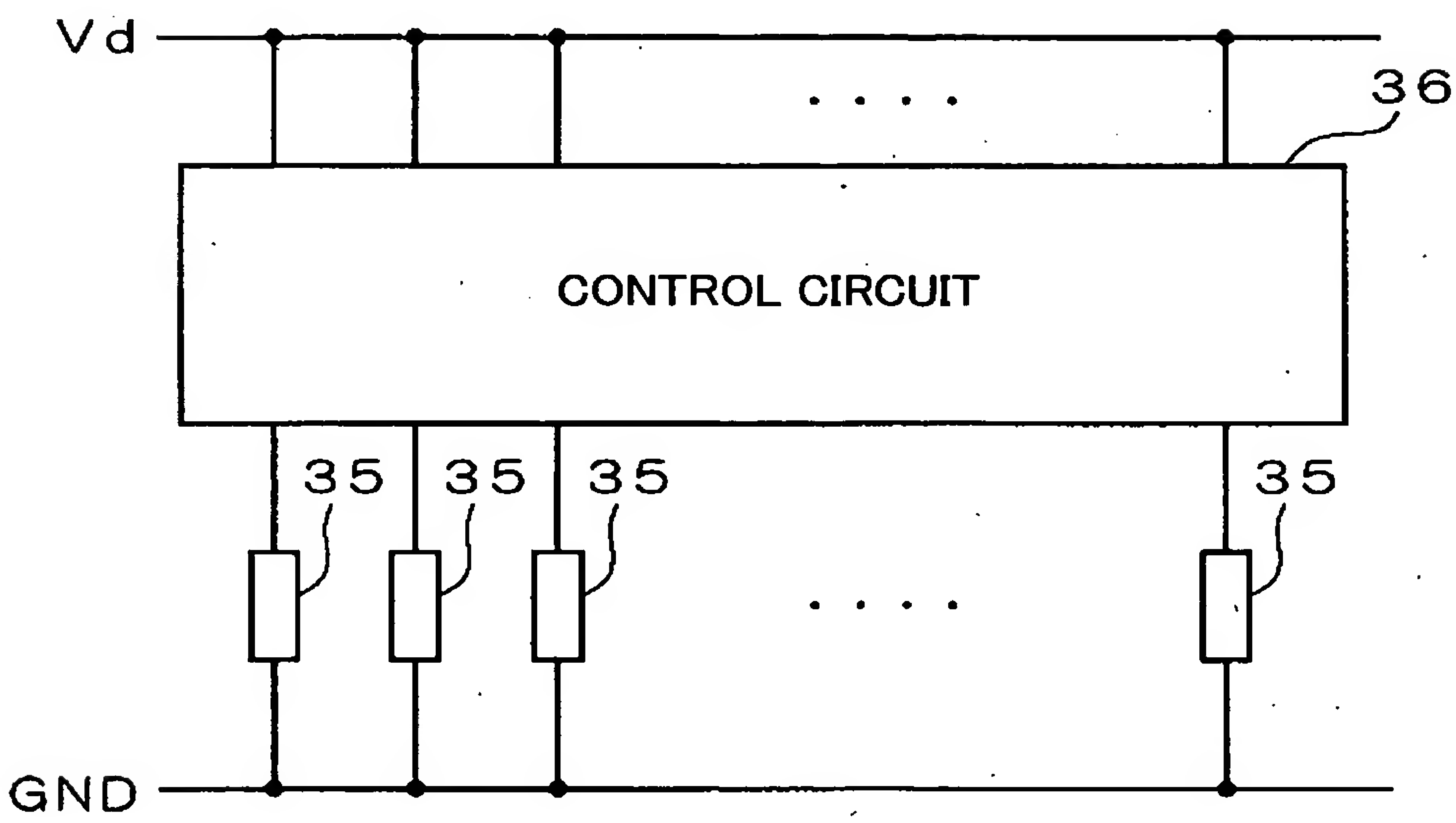


231
232
230
100
234
233
(a)
240
241
243
242
100
(b)
250
251
252
100
(c)
261
260
262
100
(d)

[FIG. 8]

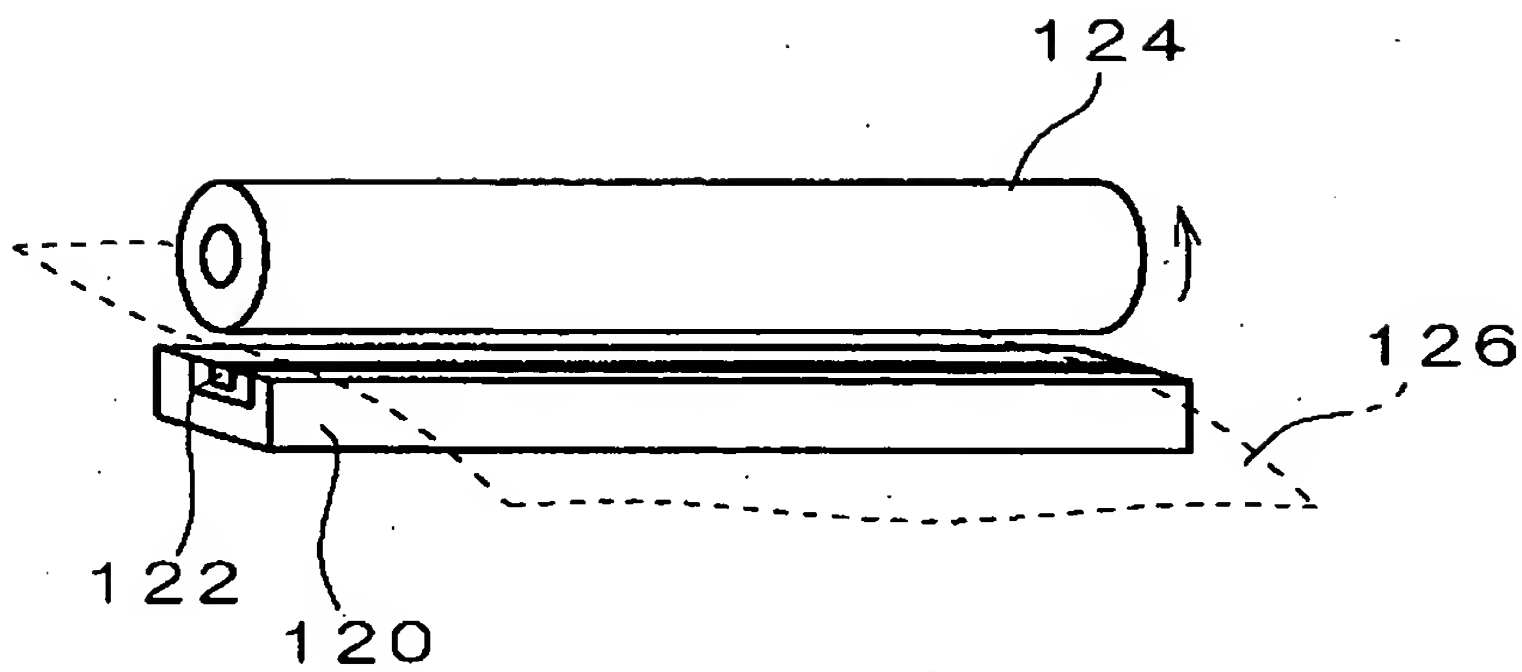


[FIG. 9]



[FIG. 10]

(a)



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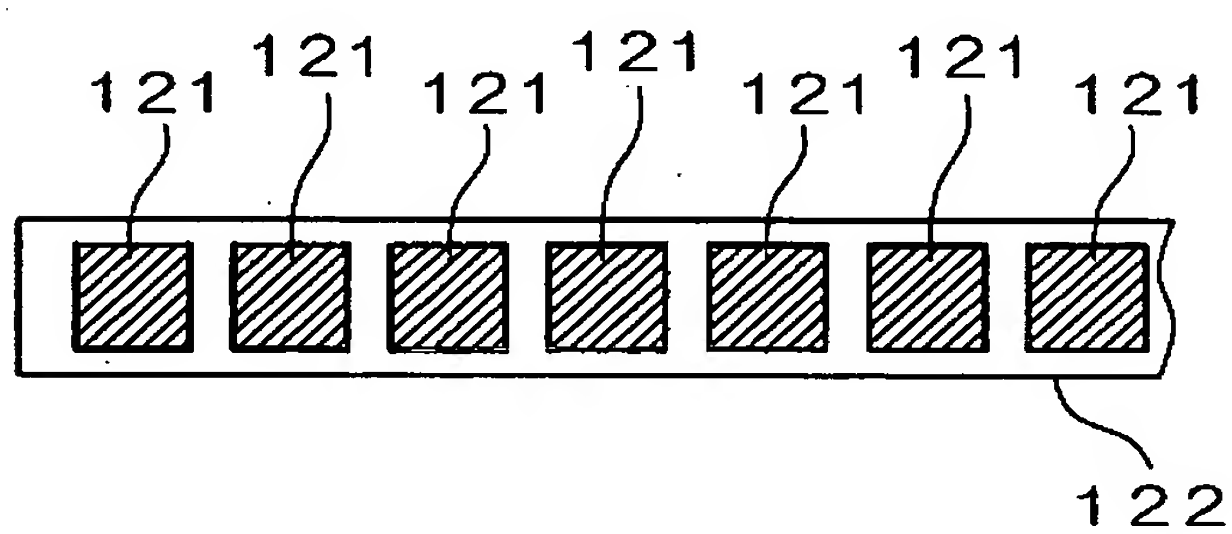
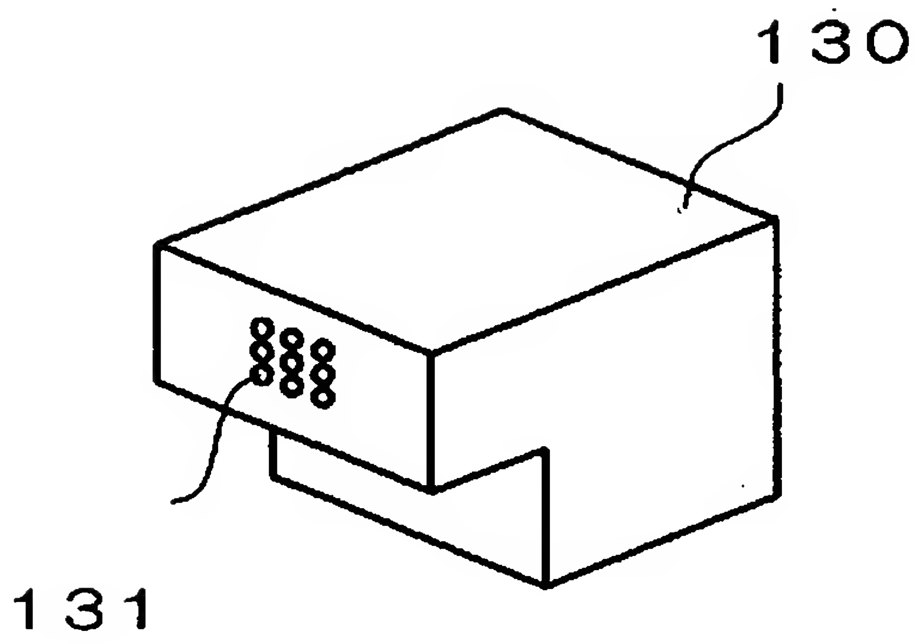


[FIG. 11]

(a)



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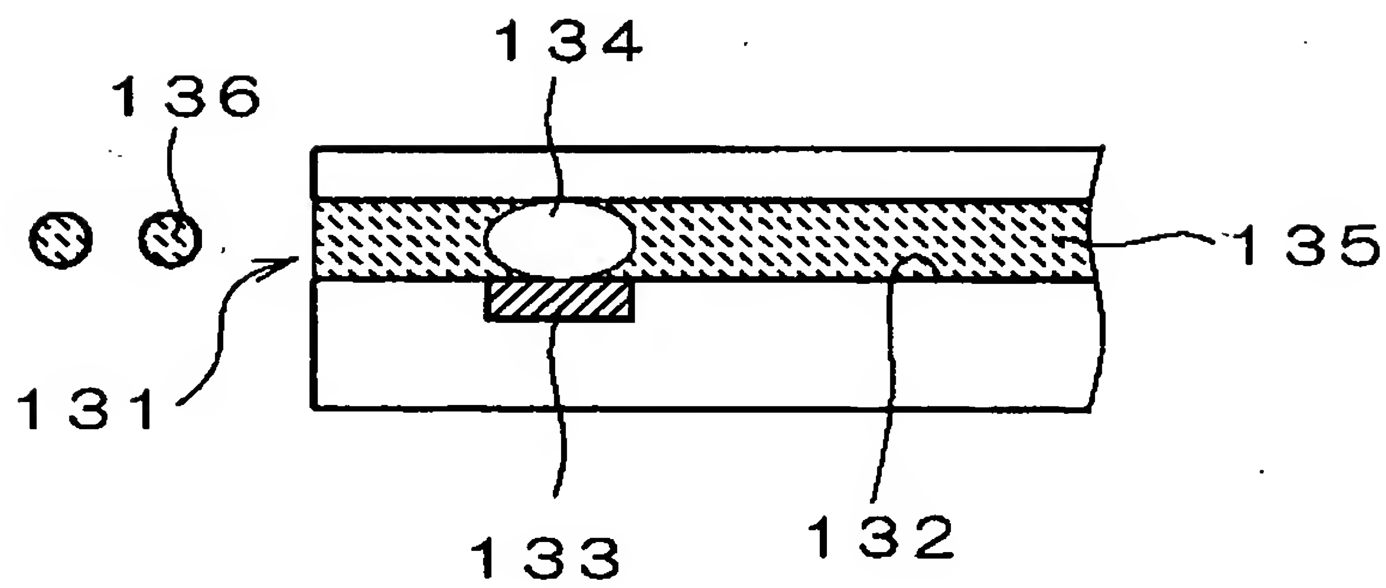

[Name of Document] ABSTRACT

[Abstract]

[Object] To prevent the performance of a driving thin-film transistor 21 of a thin-film-transistor driving and light-emitting display device from deteriorating over time while maintaining a function of allowing a large current to flow.

[Solving Means] In a driving thin-film transistor 21, a lightly doped region 27 is provided only in a drain region 25 (one-sided LDD structure). Alternatively, lightly doped regions 27 are provided in both a source region 24 and the drain region 25. The lightly doped region 27 in the drain region 25 is longer than the lightly doped region 27 in the source region 24, resulting in an asymmetrical LDD structure.

[Selected Figure] Fig. 3